HEALTH ADVISORY:

DRAFT
SAFE EATING GUIDELINES FOR FISH AND SHELLFISH FROM THE SACRAMENTO RIVER AND NORTHERN DELTA

April 2008

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FOREWORD

This draft report provides guidelines for consumption of various fish and shellfish species taken from the Sacramento River and other water bodies in the Sacramento Valley watershed. These draft guidelines were developed as a result of studies of mercury concentrations in fish tested from these water bodies, and are provided to fish consumers to assist them in making choices about the types of fish and frequency of consumption considered safe to eat. Some fish tested from these water bodies showed high mercury levels, and draft guidelines are provided to protect against possible adverse health effects from methylmercury as consumed from mercury-contaminated fish. Additionally, the draft guidelines provide information to aid consumers in selecting fish that are lower in mercury or other contaminants. Historical and preliminary data for chlorinated hydrocarbons were also considered to determine whether consumption advice more restrictive than that for mercury was warranted. This draft report provides background information and a description of the data and criteria used to develop the draft guidelines, which will be revised as appropriate following public review, and published in a final report containing the final state advisory.

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EXECUTIVE SUMMARY

The Office of Environmental Health Hazard Assessment (OEHHA) evaluated mercury levels in edible tissues of fish and shellfish caught from the Sacramento River and other water bodies (*e.g.*, creeks, sloughs) located in the Sacramento Valley. Data used in the evaluation included historical data obtained from the state Toxic Substances Monitoring Program and Surface Water Ambient Monitoring Program, the Sacramento River Watershed Program, the CALFED[1] Mercury Project, and researchers from the University of California at Davis. In addition, fish samples collected in 2005 and 2006 as part of the Fish Mercury Project, funded by the California Bay Delta Authority, were evaluated. This draft report and the safe eating guidelines contained herein pertain to fish caught from the Sacramento River just below Shasta Lake to the confluence with the San Joaquin River in Pittsburg; select creeks and sloughs associated with the Sacramento River; and other water bodies in the "Northern Delta" (defined as the Delta north of Highway 12 to Sacramento, and including the portion of the Sacramento River from Pittsburg to Rio Vista). These water bodies occur in parts of the following counties: Solano, Sacramento, Yolo, Sutter, Colusa, Yuba, Glenn, Butte, Tehama, and Shasta counties.

A previous draft advisory was issued in February 2007 for the "South Delta" that covered water bodies in the Delta south of the San Joaquin River. The boundary for the "South Delta" has been revised in this report to coordinate with the guidelines developed for the Northern Delta. Specifically, the northern boundary for the South Delta draft advisory was extended from the San Joaquin River to Highway 12 to meet the defined boundary for the Northern Delta draft advisory. This change will add fish and shellfish from the Delta region between the San Joaquin River and the Sacramento River and from water bodies north of the San Joaquin River but south of Highway 12, to the South Delta draft advisory. Samples evaluated from the area between the San Joaquin River and Highway 12 contained mercury levels consistent with other South Delta fish samples. Additionally, the name "South Delta" used in the previously issued advisory will hereafter be called the "Southern Delta."

Mercury contamination of fish is a national problem that has resulted in the issuance of fish consumption advisories in most states, including California. Mercury is a trace metal that can be toxic to humans and other organisms in sufficiently high doses. Mercury occurs naturally in the environment, and is also redistributed in the environment as a result of human activities such as mining and the burning of fossil fuels. Once mercury is released into the environment, it cycles through land, air, and water. In aquatic systems, it undergoes chemical transformation to the more toxic organic form, methylmercury, which accumulates in fish and other organisms. Almost all fish contain detectible levels of mercury, more than 95 percent of which occurs as methylmercury. Consumption of fish is the major route of exposure to methylmercury in the United States. For more information on mercury, see Appendix I.

The critical target of methylmercury toxicity is the nervous system, particularly in developing organisms such as the fetus and children. Methylmercury toxicity can occur to the fetus during pregnancy even in the absence of symptoms in the mother. In 1985, the United States Environmental Protection Agency (U.S. EPA) set a reference dose or RfD (that is the daily

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[1] CALFED is a partnership among state and federal agencies that began in 1994 when California signed an agreement with federal agencies to coordinate activities related to water supply, water quality, fisheries, and agriculture in California. The mission of the CALFED Bay-Delta Program is to improve water supply in California and ecological health in the San Francisco Bay/Sacramento-San Joaquin Delta.

exposure likely to be without significant risks of deleterious effects during a lifetime) for methylmercury of $3x10^{-4}$ milligrams per kilogram of body weight per day (mg/kg-day), based on central nervous system effects (ataxia, or loss of muscular coordination; and paresthesia, a sensation of numbness and tingling) in adults. This RfD was lowered to $1x10^{-4}$ mg/kg-day in 1995, and confirmed in 2001, based on neurodevelopmental abnormalities in infants exposed *in utero*.

OEHHA finds convincing evidence that the fetus is more sensitive than adults to the neurotoxic effects of mercury, but also recognizes that fish can play an important role in a healthy diet, particularly when it replaces other, higher fat sources of protein. These potential beneficial effects are thought to stem largely from unique fatty acids found in fish (docosahexaenoic and eicosapentaenoic acids) and include reduced rates of cardiovascular disease and stroke, decreased inflammation, and improvements in cognitive and visual function. Fish consumption during pregnancy, in particular, has been associated with higher cognitive scores in young children. Nevertheless, because the fetus has increased vulnerability to methylmercury, OEHHA will use the current U.S. EPA RfD, based on effects in the fetus, for women of childbearing age (18-45 years) and children 1-17 years. At the same time, OEHHA will encourage women ages 18-45 to select and eat fish that are low in mercury or other contaminants and high in the fatty acids described above, which can benefit the developing fetus. The previous RfD, based on effects in adults, will be used for women over 45 years and men, who are generally less sensitive to methylmercury.

The dataset for fish and shellfish from the Sacramento River and Northern Delta encompassed an exceptionally large geographic area and sample size, which included many separate and connected water bodies. Sufficient numbers of legal or edible-sized fish or shellfish were available to evaluate mercury concentrations and issue safe eating guidelines for the following species from the Sacramento River or Northern Delta: American shad, Asiatic clam, bluegill, brown bullhead, carp, channel catfish, Chinook salmon, crappie, hardhead, largemouth bass, rainbow trout, redear sunfish, Sacramento pikeminnow, Sacramento sucker, white catfish, and crayfish (mixed species). Striped bass were also collected but not evaluated. Other fish and shellfish species collected in fewer numbers or locations were hitch, goldfish, smallmouth bass, spotted bass, steelhead trout, and tule perch. Images of the fish and shellfish species are presented in Appendix II. Samples were collected from 86 locations on the Sacramento River or in creeks, sloughs, or other water bodies in the Northern Delta or associated with the Sacramento River. Statistical analysis of the data was used to compare mercury concentrations between water bodies and subdivided areas. A regional approach was determined to be appropriate to characterize the results and to communicate them. Safe eating guidelines developed for the Sacramento River and Northern Delta are shown in the tables that follow.

In order to provide safe eating guidelines for various fish species, contaminant concentrations in fish from a water body are compared to OEHHA advisory tissue levels for those chemicals. Advisory tissue levels are used by OEHHA to determine the appropriate consumption rate (quantity of fish or shellfish consumed in a given time period) that would prevent exposure to more than the average daily reference dose for non-carcinogens or to a risk level greater than $1x10^{-4}$ (one in 10,000) for carcinogens. Best professional judgment is used to determine the most suitable data evaluation approach as well as the most suitable method to convert a complex data set into more simplified and unified consumption advice for risk communication purposes. Ultimately, safe eating guidelines identify those fish species with high contaminant levels whose consumption should be avoided as well as those low-contaminant fish that may be consumed frequently as part of a healthy diet.

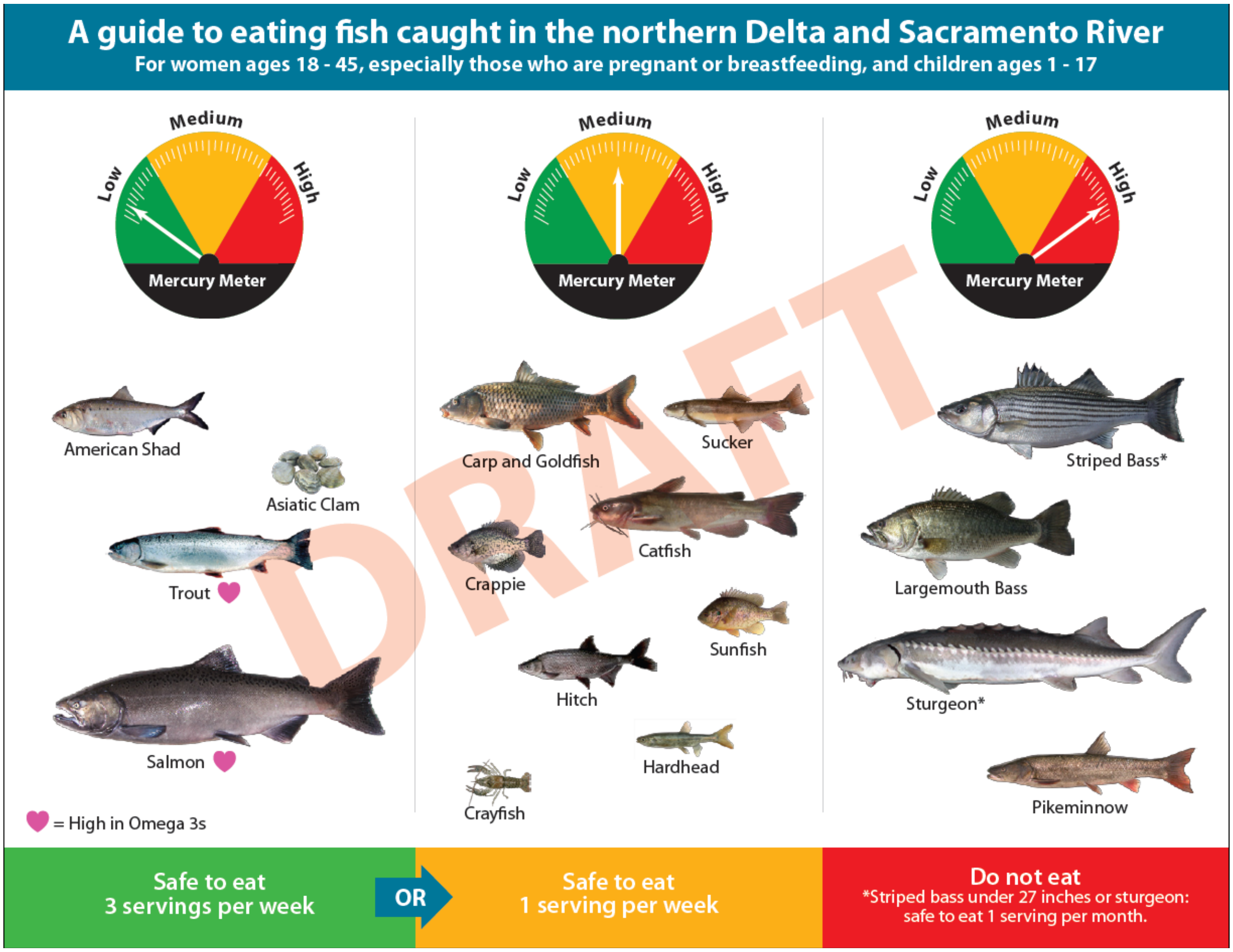
For general information on how to limit your exposure to chemical contaminants in sport fish (*e.g.*, eating smaller fish of legal size), as well as a fact sheet on methylmercury in sport fish, see the California Sport Fish Consumption Advisories (http://www.oehha.ca.gov/fish.html) and Appendices I and III. Guidelines for other California water bodies can be found online at: http://www.oehha.ca.gov/fish/so_cal/index.html. It should be noted that trimming the fat and cooking fish to remove the juices will not reduce the methylmercury content. Additionally, there are no known ways to prepare fish (such as soaking in milk) that will reduce the methylmercury content of the fish.

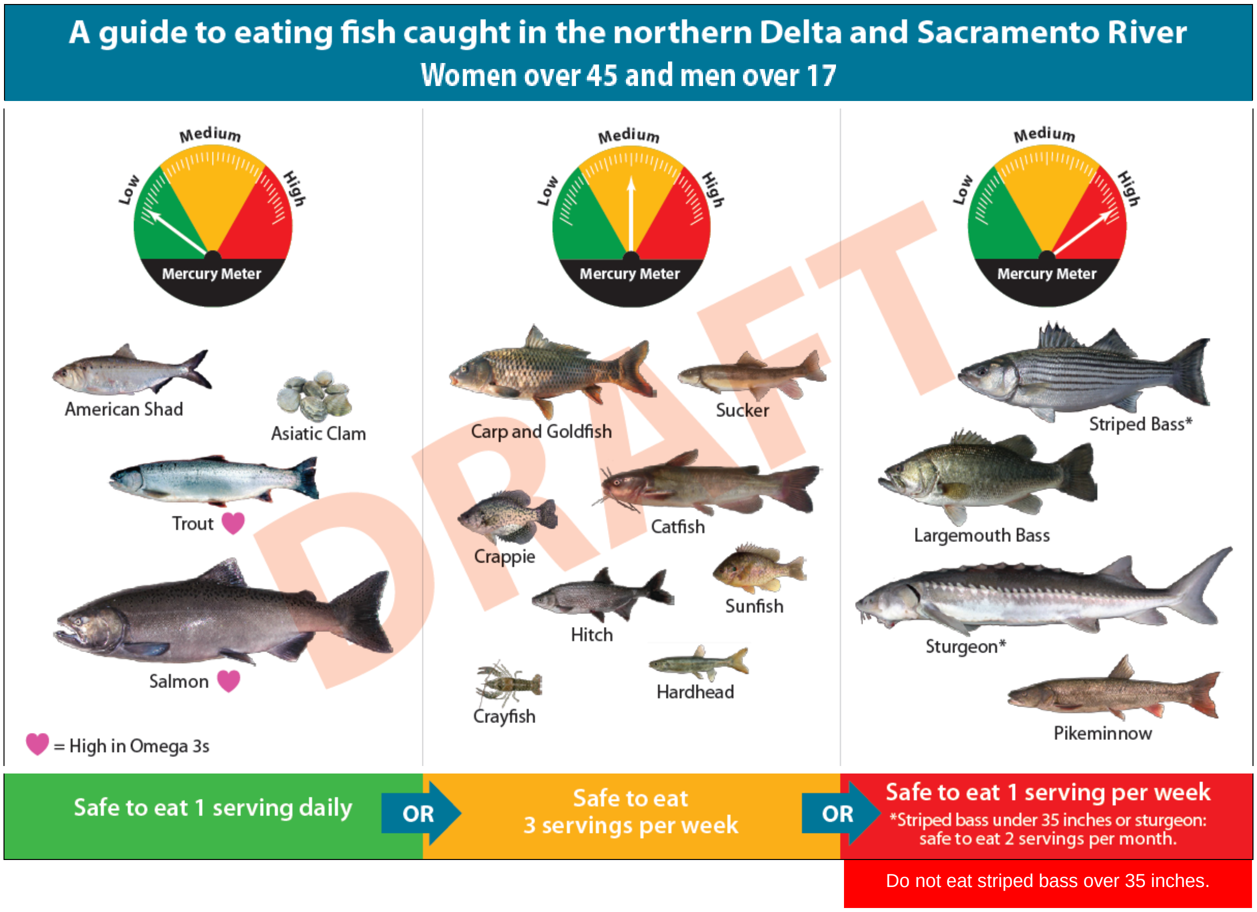
DRAFT SAFE EATING GUIDELINES

Based on Mercury in Fish from the

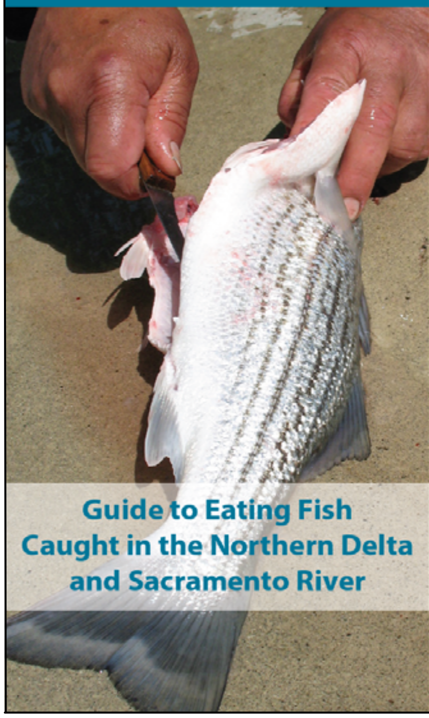
Sacramento River and Northern Delta

Including the Sacramento River from below Shasta Lake to Pittsburg
and other water bodies in the Delta north of Highway 12




A guide to eating fish caught in the northern Delta and Sacramento River
Women over 45 and men over 17
Medium
Low
High
Mercury Meter
American Shad
Asiatic Clam
Trout
Salmon
= High in Omega 3s
Carp and Goldfish
Sucker
Catfish
Crappie
Sunfish
Hitch
Hardhead
Crayfish
Striped Bass*
Largemouth Bass
Sturgeon*
Pikeminnow
DRAFT
Safe to eat 1 serving daily
OR
Safe to eat 3 servings per week
OR
Safe to eat 1 serving per week
*Striped bass under 35 inches or sturgeon: safe to eat 2 servings per month.
Do not eat striped bass over 35 inches.

Eat fish.
Be safe.
Choose wisely.



Why eat fish?

Eating fish is good for your health. Fish have Omega 3s that can reduce your risk for heart disease and improve how the brain develops in unborn babies and children.

What is the concern?

Some fish have high levels of mercury that can negatively affect how the brain develops in unborn babies and children.

What should I do?

- Use this guide to choose fish lower in mercury and high in Omega 3s.
- Eat smaller fish of legal size. Fish build up mercury in their bodies as they grow.

What is a serving?

The recommended serving of fish is about the size and thickness of your hand. Use your hand to measure a serving of fish. Give children smaller servings.

More fish eating advice for women ages 18 – 45 and children ages 1 – 17

- You can eat 2 servings per week of fish from stores or restaurants. But, do not eat fish caught by you, friends or family in the same week.
- Only one of your two servings of fish per week should be canned albacore (white) tuna.
- When shopping for fish, good choices are salmon, pollock, catfish, tilapia, and shrimp.
- Do not eat shark, swordfish, tilefish, or king mackerel. These fish are very high in mercury.

For more advice about what you can do to protect your family from mercury in fish, contact:

OEHHA

http://www.oehha.ca.gov/fish.html.

(916) 327-7319 or (510) 622-3170

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INTRODUCTION

Mercury is a trace metal that occurs naturally in the environment, and exists in various forms including elemental or metallic mercury, inorganic, and organic mercury (ATSDR, 1999; IARC, 1993). Mercury enters the environment from the breakdown of minerals in rocks and leaching from old mine sites. Cinnabar ores, naturally rich in mercury, are common in northern California, and mercury was extensively mined in California in the 1800s and early 1900s. Mercury is also emitted into air from cement kilns, the burning of fossil fuels, and other industrial sources, as well as from volcanic eruptions. Mercury contamination thus occurs as a result of both natural and anthropogenic sources and processes.

Once mercury is released into the environment, it cycles through land, air, and water. The deposition of mercury in aquatic ecosystems is a concern for public and environmental health because microorganisms (bacteria and fungi) in the sediments can convert inorganic mercury into organic methylmercury, a more toxic form of mercury. Once formed, methylmercury is ingested by aquatic animals and subsequently by the fish that feed on them. In this way, methylmercury "biomagnifies," reaching the highest levels in fish and other organisms at the top of the food web. Concentrations of methylmercury in fish tissues can therefore be orders of magnitude greater than concentrations found in the water in which they reside.

Methylmercury contamination of fish is a national problem that has resulted in the issuance of fish consumption advisories in most states, including California (U.S. EPA, 2003). Methylmercury can be toxic to humans and other organisms in sufficiently high doses and can pose a variety of human health risks (NRC/NAS, 2000). Fish consumption is the major route of human exposure to methylmercury in the United States (ATSDR, 1999). Almost all fish contain detectable levels of mercury, more than 95 percent of which occurs as methylmercury. For this reason, concentrations in fish are usually measured as total mercury, and the conservative assumption is made that the measured mercury is methylmercury. "Mercury" and "methylmercury" may thus be used interchangeably in this report. Whether consumption of fish is harmful depends on the concentrations of methylmercury in the fish and the amount of fish consumed.

Human toxicity of methylmercury has been well studied following several epidemics of human poisoning resulting from consumption of highly contaminated fish (Japan) or seed grain (Iraq, Guatemala, and Pakistan; Elhassani, 1982-83). The resulting illness was manifested largely by neurological signs and symptoms such as loss of sensation in the hands and feet and, in extreme cases, loss of gait coordination, slurred speech, sensory deficits including blindness, and mental disturbances (Bakir *et al.*, 1973; Marsh, 1987). Review of data collected during and subsequent to the Japan and Iraq outbreaks identified the critical target of methylmercury as the nervous system and the most sensitive subpopulation as the developing organism (U.S. EPA, 1997). During critical periods of prenatal and postnatal structural and functional development, the fetus and children are especially susceptible to the toxic effects of methylmercury (ATSDR, 1999; IRIS, 1995). For additional discussion of the toxicity of methylmercury, see Klasing and Brodberg (2008).

Risks from exposure to methylmercury in fish are evaluated by comparing measured concentrations to a reference dose (RfD), which is an estimate of daily human exposure to a chemical that is likely to be without significant risk of adverse effects during a lifetime (including to sensitive population subgroups), and is expressed in units of milligrams per kilogram per day (mg/kg-day; IRIS, 1995). This estimate includes a safety factor to account for data uncertainty. The underlying assumption of a RfD is that, unlike carcinogenic effects, there is a threshold dose below which certain toxic effects will not occur. The RfD for a particular chemical is derived from review of relevant toxicological and epidemiological studies in animals or humans. Based on these values and the application of uncertainty factors to account for incomplete data and sensitive subgroups of the population, a RfD is then generated. Exposure to a level above the RfD does not mean that adverse effects will occur, only that the possibility of adverse effects occurring has increased (IRIS, 1993).

The first United States Environmental Protection Agency (U.S. EPA) RfD for methylmercury was developed in 1985 and set at $3x10^{-4}$ mg/kg-day (U.S. EPA, 1997). This RfD was based on the earliest symptom of methylmercury toxicity (paresthesias or numbness and tingling sensations) that occurred in a small percentage of exposed Iraqi adults. U.S. EPA applied a 10-fold uncertainty factor to the lowest adverse effect level to generate the RfD (U.S. EPA, 1997). In 1995, U.S. EPA had sufficient data from Marsh *et al.* (1987) and Seafood Safety (1991) to develop an oral RfD based on methylmercury exposures during the prenatal stage of development (IRIS, 1995). The oral RfD from these studies was set at $1x10^{-4}$ mg/kg-day, including a 10-fold uncertainty factor, to protect against developmental neurological abnormalities in infants (IRIS, 1995). This fetal RfD was deemed protective of infants and sensitive adults.

Recently, the National Academy of Sciences was directed to provide scientific guidance to U.S. EPA on the development of a new RfD for methylmercury (NRC/NAS, 2000). Three large prospective epidemiological studies were evaluated in an attempt to provide more precise dose-response estimates for methylmercury at chronic low-dose exposures, such as might be expected to occur in the United States. The three studies were conducted in islands (the Faroe Islands, Seychelles Islands, and New Zealand) where the residents' diets rely heavily on consumption of fish and marine mammals, which provide a continual source of methylmercury exposure (NRC/NAS, 2000). The National Academy of Sciences report supported the current U.S. EPA RfD of 1x10-4 mg/kg-day for fetuses, but suggested that it should be based on the Faroe Islands study rather than Iraqi data. U.S. EPA has since published an updated RfD document that arrives at the same numerical RfD as the previous fetal RfD, using data from all three recent epidemiological studies while placing emphasis on the Faroe Island data (IRIS, 2001). For additional discussion of the derivation of the reference dose for methylmercury, see Klasing and Brodberg (2008).

The Office of Environmental Health Hazard Assessment (OEHHA) is the agency responsible for evaluating public health impacts from chemical contamination of sport fish, and issuing advisories, when needed, for the state of California. OEHHA's authorities to conduct these activities are based on mandates in the California Health and Safety Code, Section 59009, to protect public health, and Section 59011, to advise local health authorities; and the California Water Code Section 13177.5, to issue health advisories. Fish advisories developed by OEHHA are published in the California Sport Fishing Regulations of the California Department of Fish and Game. OEHHA now emphasizes "safe eating guidelines" in these advisories in an effort to inform consumers of healthy choices in fish consumption as well as those that should be avoided or restricted. For advisories based on mercury levels in fish, OEHHA will use two separate RfDs to assess risk for different population groups. The current RfD of $1x10^{-4}$ mg/kg-day, based on effects in infants, will be used for women ages 18-45 years, including pregnant and breastfeeding women, and children 1-17. The previous RfD of 3×10^{-4} mg/kg-day, based on effects in adults, will be used for women over 45 years and men.

Although evaluating contaminants that may be found in fish must be of primary concern, OEHHA has also determined that there is a significant body of evidence and general scientific consensus that eating fish at dietary levels that are easily achievable, but well above national average consumption rates, appears to promote significant health benefits, including decreased mortality. These potential beneficial effects are thought to stem largely from unique “omega-3” fatty acids found in fish (docosahexaenoic acid or DHA and eicosapentaenoic acid or EPA) and include reduced rates of cardiovascular disease and stroke, decreased inflammation, and improvements in cognitive and visual function. Fish consumption during pregnancy, in particular, has been associated with higher cognitive scores in young children. In order to take these benefits into account and best promote the overall health of the fish consumer, OEHHA has expanded the advisory process beyond a simple risk paradigm (see Klasing and Brodberg [2008] for more discussion). OEHHA encourages people of all ages, especially women 18-45 years and children, to select and eat fish that are low in mercury or other contaminants and high in “omega-3” fatty acids (DHA and EPA).

BACKGROUND

The Sacramento Valley comprises the northern section of the Central Valley and is situated in the Sacramento River hydrologic region, which contains the entire drainage area of the Sacramento River and its tributaries (Umbach, 1997). The hydrologic region begins upstream of Shasta Lake near the Oregon border and extends south to the Sacramento/San Joaquin Delta. The northern boundary for this evaluation begins at the Sacramento River just below Shasta Lake to conform to project boundaries[1], and extends to the confluence of the Sacramento and San Joaquin rivers in the Delta. The evaluation also included other water bodies such as sloughs and creeks in the northern portion of the Delta. The statutory boundary of the Delta, established in 1959 with the passage of the Delta Protection Act (Delta Protection Commission, 2006), was used here to define the western, northern, and eastern boundaries of the Northern Delta. Highway 12 was designated as the southern boundary for the Northern Delta, which divides it from the Southern Delta (Figure 1). Highway 12 was selected by OEHHA as the dividing line between the Northern and Southern Delta because it approximates the boundary between two hydrologic subareas of the Delta, as proposed by the Central Valley Regional Water Quality Control Board (CVRWQCB) and discussed further below, that corresponded to differences in mercury concentrations in fish.

Fish and shellfish from the San Joaquin Valley and Southern Delta were evaluated in the draft safe eating guidelines issued for the Southern Delta and San Joaquin River in February 2007 (Gassel *et al.*, 2007). At that time, the San Joaquin River was designated as the northern boundary of the Southern Delta. The boundaries for the Southern Delta draft advisory have been revised as presented in this report in order to coordinate with the draft fish consumption guidelines developed for the Northern Delta. The Southern Delta advisory is being revised to extend its northern boundary from the San Joaquin River to Highway 12, thereby making the Northern Delta and Southern Delta advisories contiguous (Figure 1).

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[1] The Fish Mercury Project, discussed below, was funded by a grant from the California Bay Delta Authority, which specified the project boundaries.

The Sacramento River and Northern Delta

The Sacramento River is the largest river in California, over 300 miles long, with an average annual runoff of 27 billion cubic meters (Domagalski *et al.*, 2000). The Sacramento Valley is surrounded by a mountainous and forested region, and includes at least portions of Solano, San Joaquin, Sacramento, Yolo, Placer, Yuba, Sutter, Colusa, Glenn, Butte, Tehama, and Shasta counties. Population statistics vary by county. The Sacramento Valley is the most populated region and the area of greatest water use in the Sacramento River watershed (Domagalski *et al.*, 2000). Major crops are rice, fruits, nuts, tomatoes, grapes, sugar beets, corn, alfalfa, cotton, and wheat (Domagalski *et al.*, 2000; Umbach, 1997). The agricultural economy depends on the availability of irrigation water. Water is collected in reservoirs located within the mountains surrounding the Sacramento Valley and is released for agricultural, urban, and environmental[1] purposes, and for flood control (Domagalski *et al.*, 2000). The Sacramento River also supports numerous recreational activities including fishing, hunting, boating, swimming, birding, hiking, and camping (SacramentoRiver.org, 2007). Land use in the mountainous regions is mainly forestry. The cultural roots of the region date from Native American inhabitants, such as the Wintun Indians, to settlers who established and worked farms and ranches in the 1800s (CERES, 2007).

The Sacramento River flows into the Delta where it joins the San Joaquin River (near Antioch). The confluence of these two rivers forms the Sacramento-San Joaquin Delta, and the combined rivers flow into the San Francisco estuary. The Sacramento-San Joaquin Delta is an extensive network of rivers, tributaries, and channels. Much of the Delta is below sea level and more than 1,000 miles of levees have been built for protection against flooding. The Delta's land and waterways support communities, agriculture, and recreation including fishing and boating, and provide essential habitat for several hundred species of fish and wildlife (SacDelta, 2007; Sacramento River Advisory Council, 2000).

The California Coastal Range was one of the most productive mercury districts in the world; more than 220,000,000 pounds of elemental mercury were produced from the 1840s to the early 1960s (USGS, 2006). Cache Creek and Putah Creek deliver mercury used in previous mining within the Coast Range to the Sacramento Valley. Mercury can also enter the Sacramento River from the Sierra Nevada, where it was used in historical gold mining (Domagalski *et al.*, 2000). Millions of pounds of mercury were transported to the Sierra and used to extract gold, especially in hydraulic placer mining operations. Some of the mercury and gold mines in the vicinity of the Sacramento Valley and Delta are shown in Figure 2.

Elevated levels of mercury have been found in fish from numerous lakes, reservoirs, and rivers in northern California. As a result, fish consumption advisories based on mercury contamination have been issued by OEHHA for various water bodies in at least 29 counties in central and northern California. In an effort to assess mercury levels in fish from other northern California water bodies that may have been impacted by mining or other sources of mercury, OEHHA evaluated data from fish and shellfish samples collected from water bodies in California's Sacramento Valley and Delta (Figure 3). The focus of the evaluation described in this report was 1) the Sacramento River from Shasta Lake in Shasta County to the river's confluence with the San Joaquin River in Sacramento County, 2) select creeks and sloughs associated with the

[1] Placement of dams, however, has blocked migration routes for anadromous salmonid fish species, including steelhead and Chinook salmon, and is thus thought to be an important factor in the decline of these species.

Sacramento River, including Big Chico Creek, Butte Creek, Colusa Drain, Sutter Bypass, Cross Canal, Reclamation Slough, and Sacramento Slough and 3) other small water bodies in the Northern Delta including Beach Lake, Green's Lake, Little Holland Tract, Little Hastings Tract, Delta Meadows, Delta Cross Canal, Toe Drain, the Deep Water Ship Channel, and the following sloughs: Bypass, Cache, Georgiana, Lindsey, Miner, Prospect, Snodgrass, and Steamboat sloughs. All sampling locations are shown in Table 1 and Figures 4 and 5.

Fish Species in the Sacramento River and Delta

Popular fish species in the Sacramento River and Northern Delta include Chinook and kokanee salmon; rainbow, steelhead and brown trout; white catfish, channel catfish, and bullheads; largemouth, smallmouth, and spotted bass; bluegill and other sunfishes (*e.g.*, redear sunfish), and striped bass. Crappie, sturgeon, and shad are also sought by sport fishers (River Pirate, 2007; Sacramento River Advisory Council, 2000). Other fish species in water bodies in this area include Sacramento pikeminnow, Sacramento sucker, Sacramento perch, hitch, carp, and goldfish. Crayfish are also plentiful in some areas in the Delta. Images of the fish and shellfish species are presented in Appendix II.

Data Sources

A large dataset on mercury concentrations in fish and shellfish from the Sacramento River and Northern Delta was recently collected under a grant from the California Bay-Delta Authority (CBDA). This study, the Fish Mercury Project (FMP), was initiated in 2005 to further examine mercury in fish in the Bay-Delta watershed. OEHHA worked collaboratively on this project with researchers from the University of California at Davis (UCD); the California Department of Fish and Game (CDFG), Moss Landing Marine Laboratory (MLML); the California Department of Public Health (CDPH, formerly the California Department of Health Services); and the San Francisco Estuary Institute (SFEI). In 2006, the second year of the FMP, sampling focused on the Sacramento Valley including the Sacramento River and other water bodies in the Sacramento Delta or "Northern Delta" in order to support evaluation of mercury concentrations in fish from this area. OEHHA identified target fish species for 35 locations on the Sacramento River or from other water bodies in the Northern Delta for sampling under the FMP in 2006. Several additional locations were also sampled by CDFG staff for the CVRWQCB. Fish samples that were collected from the same area in 2005 by other researchers associated with the FMP were also included in the evaluation.

An assessment of fish from Shasta Lake and other northern California reservoirs that were also sampled in the FMP will be conducted in future evaluations. OEHHA has also issued draft safe eating guidelines previously for the Lower American River and the Lower Feather River, two of the Sacramento River tributaries. Other rivers in the northern Central Valley include the Cosumnes, Bear, and Yuba Rivers, which were evaluated in prior advisories (see www.oehha.ca.gov/fish.html for further information).

Fish tissue data from the FMP for the Sacramento River and Northern Delta were merged with historical data collected by the Sacramento River Watershed Program (SRWP[1]), the CALFED

[1] The Sacramento River Watershed Program was founded in 1996 to sustain, restore, and enhance current and potential watershed resources. The SRWP operates through collaborative partnerships and conducts monitoring activities to assess water quality and other indicators of watershed health.

Mercury Project[1], the Toxic Substances Monitoring Program (TSMP) and Surface Water Ambient Monitoring Program (SWAMP)[2], and researchers from UCD[3]. In 2003, the CVRWQCB organized the historical mercury data into a single electronic database; some corrections were made to originally published data at that time. OEHHA received and reviewed the dataset, and data suitable for developing advisories were selected using OEHHA's criteria for minimum sizes and data reliability, as follows. Each sample was verified using the original dataset to address discrepancies and correct errors. Samples identified as potential duplicates were confirmed as duplicates and therefore eliminated. Latitudinal and longitudinal coordinates for mapping the sampling sites, and site names, were also reviewed and corrected as necessary. Subsequently, OEHHA compared and verified each sample with a statewide database built and maintained by SFEI for SWAMP. Samples from the SFEI database that did not occur in the file received from the CVRWQCB were added to the dataset used in this evaluation after verifying each sample with the original project data from which it was derived. Fish samples used by OEHHA to develop safe eating guidelines must meet minimum size requirements as stipulated by CDFG regulation or by OEHHA. For species that do not have a legal minimum size (or slot limit) determined by CDFG, OEHHA has established minimum "edible" sizes corresponding roughly to average length at maturity for the species (Gassel and Brodberg, 2005). Minimum legal or edible size criteria are shown in Table 2.

OEHHA merged site location spreadsheets from SFEI, TSMP, FMP, and the CVRWQCB to create a file to link tissue data with spatial locations for each sampling site. This spatially-enabled spreadsheet was brought into ArcMap, v 9.2 to create a site location shapefile of all sites, the result of which revealed some inaccurate spatial information. Spatial datasets varied with regard to documentation and accuracy. Some locations were created using Global Positioning System and others from site names. Sampling sites were discovered with similar names but in different locations, and in some cases, coordinates that were provided for some sampling site locations clearly placed them either in an incorrect location or in an inappropriately named location. OEHHA made every effort to ensure that the site location spreadsheets from the various sampling programs were accurate, and followed up by making verification inquiries with original researchers or sampling staff. Potential errors were explored and corrected as feasible. Several sampling sites were excluded when it was not possible to verify their locations (see Appendix IV). OEHHA reviewed and cross-checked the sampling locations provided by name and usually by latitude/longitude and coordinate system. Layers such as the NAD 27 California Hydrography layer (rivers and water bodies) originated by the Teale Geographic Information Systems (GIS) Solutions Group, were downloaded from the California Spatial Information Library (http://gis.ca.gov/casil/gis.ca.gov/teale/hydro/). Once the spatial information was reasonably dependable, maps were created and used to determine distance between sites and logical groupings of sampling sites for statistical analysis. The resulting database can be linked to hydrology, watershed, and Delta subregion characteristics in an ArcView GIS environment.

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[1] The CALFED Mercury Project was funded by the CALFED Bay-Delta Program to investigate mercury cycling in the Bay-Delta System.

[2] TSMP, a state water quality-monitoring program managed by the State Water Resources Control Board, was initiated in 1976 and continued until it was subsumed under the Surface Water Ambient Monitoring Program or SWAMP in 1997. CDFG collects and analyzes the samples.

[3] Data from studies by UCD were supplied by electronic mail by Darell Slotton and Shaun Ayers from UCD. CALFED data were obtained from Ben Greenfield at SFEI as electronic spreadsheets. TSMP and SWAMP data are maintained in OEHHA's data files after being downloaded from the SWRCB's web site.

Collection and Preparation of Samples

Staff from CDFG MLML collected samples of the following fish species: American shad, bluegill, carp, channel catfish, Chinook salmon, goldfish, crappie, hardhead, hitch, largemouth bass, rainbow trout, redear sunfish, Sacramento pikeminnow, Sacramento sucker, smallmouth bass, spotted bass, steelhead, striped bass, sturgeon, tule perch, and white catfish, primarily using electroshocking boats and occasionally nets. Fish were measured (in total length) and weighed, and individual fish were analyzed for mercury as skinless fillets using a Perkin Elmer Flow Injection Mercury System (FIMS) or Milestone Direct Mercury Analyzer (DMA). Staff from MLML also collected and analyzed fish for the CALFED Mercury Project and the SRWP using the same methods used in the FMP. However, some fish species were prepared differently for analysis[1], and some samples were analyzed as composites.

Fish sampled under TSMP and SWAMP were collected by staff from CDFG, Water Pollution Control Laboratory (WPCL), using electrofishing equipment, nets, and hook and line. Fish species included American shad, brown bullhead, carp, channel catfish, signal crayfish, hardhead, largemouth bass, rainbow trout, redear sunfish, Sacramento pikeminnow, Sacramento sucker, smallmouth bass, and white catfish, although for a number of these species, only one or a few individuals of legal or edible size were collected. Fish were measured (in fork length) and weighed, and analyzed as individuals or composites using skin-off muscle fillet[2]. Prior to 1997, composite samples were homogenized at the WPCL and analyzed for total mercury by cold vapor atomic absorption spectrophotometry; since 1997, samples were analyzed for mercury and other trace metals by MLML using FIMS or DMA.

Researchers from UCD collected Asiatic clams primarily by hand, and crayfish (signal crayfish, red swamp crayfish, and a single northern crayfish) using baited traps, from numerous locations in the Northern Delta. Clams were maintained live in clean water, changed twice a day for four days to purge them of all major gut contents and associated sediment, and frozen for storage. Crayfish were also frozen after digestive tracts were removed (Slotton *et al.*, 2002). Clams were measured as the maximum shell diameter and weighed, and soft tissues were extracted for analysis of total mercury and, for some of the samples, methylmercury. Clams were analyzed either as individuals or composites. Crayfish were measured as carapace length and weighed; tail muscle was extracted and analyzed for total mercury. Crayfish were analyzed as individuals. Shellfish samples were dried at 60°C, powdered, and analyzed on a dry weight basis for total mercury by UCD using a FIMS cold vapor atomic absorption system (Slotton *et al.*, 2002). Moisture percentage was determined for all sample types to allow conversion of dry weight analytical results. Wet weight concentrations were calculated using a consistent multiplier determined from moisture percentage for sample type; a multiplier of 0.1312 was used for clam data and 0.22 was used for crayfish (Ayers, 2006). Some clams were analyzed for methylmercury concentrations by Battelle Marine Science Laboratories in Sequim Washington (Slotton *et al.*, 2002). Measures of methylmercury (compared to total mercury) provide more accurate representations of the levels in shellfish such as clams because the proportion of methylmercury is more variable and generally much lower than it is in finfish. Most clam

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[1] White catfish and bullheads from the CALFED study "Contaminant Concentrations in Fish from the Sacramento-San Joaquin Delta and Lower San Joaquin River, 1998" (Davis *et al.*, 2000) were prepared as skin off fillets. Other species (*e.g.*, bass) were prepared as skin-on fillets.

[2] TSMP has historically prepared samples as skin-off muscle fillets in accordance with guidance from OEHHA when the program was founded.

samples, however, were analyzed only for total mercury. Therefore, total mercury was used in the evaluation. Concentrations of methylmercury in the clam samples, when measured, were lower than total mercury.

Sufficient numbers of legal or edible-sized fish or shellfish were available to evaluate mercury concentrations and issue safe eating guidelines for the following species from the Sacramento River or Northern Delta: American shad, Asiatic clam, bluegill, brown bullhead, carp, channel catfish, Chinook salmon, crappie, hardhead, largemouth bass, rainbow trout, redear sunfish, Sacramento pikeminnow, Sacramento sucker, white catfish, and crayfish (mixed species). Striped bass were also collected but not evaluated, as described further below. Other fish and shellfish species collected in fewer numbers or locations were hitch, goldfish, smallmouth bass, spotted bass, steelhead trout, and tule perch. When possible, these species were compared to closely related species to develop guidelines for consumption. Samples were collected from 86 locations on the Sacramento River or in creeks, sloughs, or other water bodies in the Northern Delta or associated with the Sacramento River. Sampling sites are listed in Table 1 and shown in Figures 4 and 5.

Other Contaminants

In addition to the data on mercury concentrations, OEHHA evaluated fish samples that were analyzed for chlorinated hydrocarbon contaminants including pesticides and polychlorinated biphenyls (PCBs). Fish tissues collected under the FMP in 2005 and 2006 were archived for analysis of chlorinated hydrocarbon contaminants pending receipt of funding from other sources. Some of these samples were subsequently analyzed at the WPCL and the preliminary data were made available to OEHHA. Although the FMP data were not public at the time of writing, OEHHA reviewed the data in draft form for this evaluation. In addition, chlorinated hydrocarbon contaminants were also measured in a limited number of historical samples of fish and shellfish in TSMP and SRWP. OEHHA downloaded TSMP data from the State Water Resources Control Board Web site (http://www.swrcb.ca.gov/swamp/mussel_watch.html) and received a data file from SFEI containing results from analysis of chlorinated hydrocarbon contaminants in fish samples by SRWP. OEHHA was not able to verify each sample from SRWP with the original datasets. SRWP data files received directly from the laboratory contained values for the sum of PCB congeners that did not match those included in the SFEI data file for SRWP. The differences were discussed with SFEI staff and OEHHA decided to use the SFEI data file because it contained complete results for individual congeners whereas the file from the laboratory included only summary values, and therefore, it was not possible to verify these values. Only those samples collected and analyzed since 1997 were used in this evaluation because analytical methods, including detection limits, have greatly improved over time and older data were considered less reliable. In addition, review of the historical dataset by OEHHA and SFEI (Greenfield *et al.*, 2004) showed that concentrations for these chemical groups have decreased substantially since the older data were obtained. OEHHA used the combined contaminant data from the FMP and historical datasets to determine whether any locations showed excessively high concentrations of total chlordanes, dieldrin, toxaphene, total dichlorodiphenyltrichloroethane and its metabolites (DDTs), or total PCBs, common contaminants found in California sport fish. Sixty-one samples were available for evaluation of chlorinated hydrocarbon contaminants from SRWP and TSMP; and the FMP provided results for 36 samples from the Sacramento River and Northern Delta.

Evaluation Approach

Some of the historical data used in this evaluation were not collected specifically with the intention of developing fish consumption advisories; however, they can be used for that purpose providing certain sampling criteria are met. For example, U.S. EPA recommends a minimum of three replicate composite samples of three fish per composite (nine total fish) in order to begin assessing the magnitude of contamination at a site. U.S. EPA also recommends that at least two fish species be sampled per location. Although composite analysis is generally the most cost-efficient method of estimating the average concentration of chemicals in a fish species, analysis of individual fish provides a better measure of the range and variability of contaminant levels in a fish population (U.S. EPA, 2000a). Using these guidelines, OEHHA believes that a minimum of three replicates of three fish per composite or, preferably, nine individual fish samples of multiple species constitute the minimum acceptable sample size for a sampling site that will provide representative mean concentrations of chemicals for the fish populations in a water body with, approximately, a one-mile radius.

The Sacramento River and other water bodies in the Northern Delta cover an extensive geographic range, and the Delta is comprised of numerous rivers, creeks, channels, sloughs, and wetlands. Therefore, evaluation of the data for this large and complex area required a different approach than what is described above in which two species each represented by a minimum of nine individuals per location are considered for the development of consumption guidelines for that particular water body. This alternate approach, explained below, relied heavily on creation of a GIS-linked database and maps for evaluations.

Summary statistics including mean mercury concentrations for fish and shellfish from the Sacramento River and Northern Delta were calculated for each sampling location. All sampling sites from the Sacramento River area and Northern Delta evaluated in this draft report are listed in Table 1, which shows site names as revised to represent combined locations (*i.e.*, when sampling sites on the same water body were within approximately one mile of each other). The table also indicates when more than one project sampled the same location. Original site names are shown when they differed from the revised name, and are also provided in the case summaries in Appendix V. Mean mercury concentrations were compared across all sampling locations and within and across subdivided areas of the overall region using a step-wise process to determine the most logical way to organize data from different locations, or groupings of locations, in order to develop safe eating guidelines.

After reviewing similarities and differences in the summary statistics, multiple regression correlation analysis (MRC) was used to compare locations by assessing the degree to which fish length and location influenced mean mercury concentrations. Fish length is known to be an important variable that correlates with mercury concentrations for many species. Furthermore, MRC can be used to assess the influence of location after controlling for differences in fish length between these locations. MRC was performed using white catfish, largemouth bass, Sacramento pikeminnow, and Sacramento sucker samples, the four species that were collected in large numbers from different parts of the overall region and therefore provided sufficient results to perform the analysis.

Samples were first grouped according to whether they were collected in the Northern Delta, or outside of the Delta, and whether they were from the Sacramento River, or other water bodies resulting in four subregions: 1) Northern Delta, Sacramento River, 2) Northern Delta, non-river, 3) non-Delta, Sacramento River, and 4) non-Delta, non-river (as designated in Table 1).

Statistical comparisons of these four areas using MRC did not reveal any consistent patterns in mercury concentrations, and therefore, these groupings were not continued.

The next step made use of hydrologic "subareas" as proposed by the CVRWQCB and presented in a draft report in which the CVRWQCB divided the Sacramento-San Joaquin Delta (defined by statute) into eight regions based on hydrologic characteristics and mixing of source waters (CVRWQCB, 2006; Figure 6). This approach was also used in the evaluation and development of draft advisories for the San Joaquin River and Southern Delta. It should be noted that the CVRWQCB "subareas" are preliminary and subject to approval during the process of developing a Total Maximum Daily Load for methylmercury for the Delta. Nevertheless, OEHHA used the CVRWQCB subareas to evaluate fish and shellfish from the Delta because they provided a logical means of organizing the data for this large area. MRC was used to test for differences between subareas. The results of this analysis, as described below, were used to make determinations of how to organize the data and develop safe eating guidelines.

EVALUATION OF MERCURY LEVELS IN FISH AND SHELLFISH FROM THE SACRAMENTO RIVER AND NORTHERN DELTA

Mercury concentrations in fish and other biota are dependent, in general, on the mercury level of the environment, which can vary based on differences in pH, redox potential, temperature, alkalinity, buffering capacity, suspended sediment load, and geomorphology of individual water bodies (Andren and Nriagu, 1979; Berlin, 1986; WHO, 1989). Other factors also affect the accumulation of mercury in fish tissue, including fish diet, species and age (as inferred from length) (WHO, 1989; 1990). Fish at the highest trophic levels (*i.e.,* predatory fish) generally have the highest levels of mercury. Additionally, because of the long biological half-life of methylmercury in fish (approximately 2 years), tissue concentrations in fish increase with increased duration of exposure (Krehl, 1972; Stopford and Goldwater, 1975; Tollefson and Cordle, 1986). As a result, tissue methylmercury concentrations are expected to increase with increasing age and length within a given species, particularly in piscivorous fish.

Chemical concentrations for the data are reported in wet weight. Arithmetic means, rather than geometric means, were used to represent the central tendency (average) of mercury concentrations for all species in this report. In general, arithmetic means for environmental chemical exposures are more health-protective than geometric means, and are commonly used in human health risk assessments. OEHHA evaluated mercury concentrations in 1,429 fish and shellfish samples (including a total of 2,194 individuals) from a total of 60 sampling sites[1] on the Sacramento River and other water bodies principally in the Northern Delta. The mean mercury concentrations, lengths, and sample sizes for each species are shown in Table 3. Mercury concentrations, lengths, and sampling sites for each unique sample are presented in the case summaries in Appendix V. All fish lengths that were reported in fork length were converted to total length for the purpose of calculating mean lengths; conversion factors for estimating total length from measured fork lengths were determined for each species by OEHHA based on the

[1] Sampling sites from the same water body within a one-mile radius were combined. Some of these locations were sampled under different projects sampling in the same area. As a result, the original reported number of sampling sites (86) was reduced to 60.

degree of the angle in the fork of the tail fin because species-specific conversion factors were not available. The lengths as originally reported are included in Appendix V.

The species with the lowest overall mean mercury concentrations were American shad, Asiatic clams, Chinook salmon, and steelhead and rainbow trout, followed by red swamp crayfish and redear sunfish. Bluegill, sucker, signal crayfish, brown bullhead, carp, hardhead, channel catfish, crappie, and white catfish had somewhat higher levels of mercury. Black bass (including largemouth, smallmouth, and spotted bass) and Sacramento pikeminnow had the highest mercury levels. To develop safe eating guidelines, the degree of variability in chemical concentrations in the species and geographic differences were considered. Additionally, other factors such as the ease of communicating the advice needed to be addressed. Further discussion of these considerations is provided below.

Comparisons of subareas

Mean mercury concentrations were calculated for each species in each Northern Delta subarea[1] (Table 4). To test for regional differences in mercury levels in the Northern Delta, MRC was performed on white catfish, largemouth bass, Sacramento sucker, and Sacramento pikeminnow collected from CVRWQCB proposed Northern Delta subareas. The following three subareas are located in the Northern Delta: Delta Yolo Bypass South, Delta Yolo Bypass North, and the Delta Sacramento River subarea[2] (Figure 6, Northern Delta subarea names shown in bold). As can be seen in Figure 6, a small portion of the Delta Central Delta subarea is located between the Sacramento and San Joaquin Rivers. Samples from these locations, including White Slough and Potato Slough, were previously evaluated for the Southern Delta draft advisory. These samples were not specifically included in that draft advisory, however, because the San Joaquin River was selected to represent the northern boundary of the Southern Delta to simplify the description of it, and these samples were collected from the area north of the San Joaquin River. Comparisons of the three Northern Delta subareas, with samples from the northern portion of the Delta Central Delta subarea included as a fourth subarea, confirmed that mercury concentrations in these samples (from White Slough and Potato Slough) were consistent with fish and shellfish from the remainder of the Delta Central Delta subarea, south of the San Joaquin River, which had lower mercury concentrations than samples of the same species in the Northern Delta. A summary of the results in Table 5 shows differences in mean mercury concentrations between subareas; the full results of the MRC analysis are provided in Appendix VI. OEHHA therefore concluded that the Delta Central Delta subarea, both north and south of the San Joaquin River, should be considered together as part of the Southern Delta draft safe eating guidelines. As a result, it was necessary to change the boundary of the Southern Delta draft safe eating guidelines. As stated above, the location of Highway 12 approximated the northern boundary of the Delta Central Delta subarea and provided a simpler and more recognizable way to describe the boundary compared to the subarea boundary itself.

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[1] The part of the Sacramento River outside the Delta is not included in the subareas defined by the CVRWQCB. Likewise, creeks and sloughs located outside the Delta are not part of any subarea. For comparisons, however, summary statistics were also calculated for the samples from these two areas, as shown in Table 4.

[2] One sampling site, Sacramento River at Decker Island, is located within the Delta West Delta subarea. However, because it is on the Sacramento River, it was included in this evaluation and advisory. The only species collected there were clams and crayfish. Two sturgeon were collected from the Sacramento River at Channel Marker 33, also in the Delta West Delta subarea; however, sturgeon were not evaluated.

Comparisons of mercury concentrations between the three Northern Delta subareas (Delta Yolo Bypass South, Delta Yolo Bypass North, and the Delta Sacramento River subarea) were repeated (excluding the Delta Central Delta subarea). In this evaluation, MRC results showed that location (subarea) was significant in only one of four species, largemouth bass, and explained less than two percent of the mercury variance[1] (Appendix VII). These findings confirmed that the Delta Central Delta differed from the three Northern Delta subareas because subarea explained a larger percent of the variance when the Delta Central Delta subarea was included in the analysis. Furthermore, the results indicated that mercury levels in fish from the three Northern Delta subareas were not different and it would not be appropriate to issue different consumption advice for each Northern Delta subarea.

This analysis did not address mercury concentrations in samples collected from the Sacramento River and other water bodies north of (outside) the Delta. Therefore, the samples from the Sacramento River and other creeks and sloughs[2] associated with the Sacramento River outside the Delta were considered as a "subregion" and compared to samples from the Northern Delta using MRC. The Northern Delta subareas were combined and also considered a "subregion." As before, white catfish, largemouth bass, Sacramento sucker, and Sacramento pikeminnow were used in the analysis, and carp was also tested due to its large sample size in the two subregions. The results of this analysis (Appendix VIII) showed that after controlling for length in each species, the influence of location was not significant in white catfish, Sacramento pikeminnow, or carp. Location was significant in Sacramento sucker and largemouth bass, although location (subregion) explained only three percent of the mercury variance in these two species, whereas length explained 45 percent and 36 percent of the mercury variance in sucker and largemouth bass, respectively. The interaction variable was also significant for largemouth bass, which makes it more difficult to interpret the small percentage of variance explained by location. Location was therefore not considered an important variable and based on these results, it was concluded that these two subregions, the Northern Delta, and the Sacramento River and associated creeks and sloughs outside the Delta, would be considered as one combined region for safe eating guidelines, which were based on the overall grand mean mercury concentrations for each species.

Mean mercury concentrations for fish and shellfish species and species groups

OEHHA has developed advisory tissue levels for methylmercury and other contaminants found in fish (Klasing and Brodberg, 2008) similar to risk-based consumption limits recommended by U.S. EPA (2000b). Advisory tissue levels relate the number and size of recommended fish meals to mercury concentrations found in fish (Table 6). These values were designed so that individuals consuming no more than a preset number of meals should not exceed the RfD for methylmercury or other contaminants, on average, or a risk level of $1x10^{-4}$ for carcinogens. Meal sizes were based on a standard eight-ounce (227 grams) portion of uncooked fish, which is approximately six ounces after cooking, for adults who weigh roughly 70 kilograms (equivalent to 154 pounds). OEHHA recommends that people who weigh less than 70 kilograms eat smaller portions of fish and that, in particular, children up to age 12 eat about half as much as adults.

[1] For white catfish, location was barely non-significant (p=0.053), and the interaction variable was significant.

[2] Big Chico Creek, Butte Creek, Colusa Drain, Sutter Bypass, Cross Canal, Reclamation Slough, and Sacramento Slough

Advisory tissue levels for methylmercury for women over 45 years and men are approximately three times higher than for sensitive populations because of the three-fold higher RfD level used for this population group. The sensitive population is defined as women 18-45 years (including women who are pregnant or breastfeeding) and children 1-17.

To simplify consumption advice, OEHHA commonly combines related species in safe eating guidelines. Individual related species can be hard to differentiate and usually have similar mercury levels. Typically, small sunfish species (including bluegill, green sunfish, and redear sunfish) are combined, as are black bass species (largemouth, smallmouth, and spotted bass) and crayfish (northern, signal, and red swamp crayfish). Catfish species, including bullheads, are also commonly combined, as are trout species. When sampled, carp and goldfish are also combined.

Two sunfish species were collected in sufficient numbers for evaluation in the Sacramento River and Northern Delta: bluegill and redear sunfish. The mean mercury concentrations in redear sunfish were generally lower than in bluegill as reflected by their overall mean concentrations of 0.14 ppm and 0.19 ppm, respectively (Table 3). The mean concentrations were within a fairly narrow range, however, and the overall mean mercury concentration for all bluegill and redear sunfish samples combined (0.16 ppm) was used to develop guidelines for this species group.

Data for three catfish species (white catfish, channel catfish, and brown bullhead) were available for this evaluation. White catfish were generally found to have more variable and higher concentrations of mercury than channel catfish and brown bullhead (0.44 ppm, 0.28 ppm, and 0.24 ppm, respectively; Table 4), although MRC showed that location was not a significant factor. Mean mercury concentrations in white catfish varied among sampling sites within subareas and were in the "no consumption" range for women ages 18-45 and children ages 1-17 at the following locations in the Northern Delta: Sacramento River at Hood, Cache Slough near Ryer Island Ferry, Little Holland Tract, and Toe Drain; and outside the Delta in Sacramento Slough. Basing advice on the overall mean mercury concentration for the three species combined would keep the safe eating guidelines for catfish consistent and simpler, but might lead to some consumption of higher-mercury white catfish. It is unclear why white catfish in these locations have higher mercury concentrations, and this environmental variability can not be explained or easily incorporated in the advice. Separating out white catfish would be more health protective but would complicate the safe eating guidelines. OEHHA decided not to separate them, and to base the guidelines on the grand mean for all catfish species sampled (0.38 ppm).

Crayfish were collected from throughout the Northern Delta. Crayfish species also varied in mean mercury concentrations, but can be difficult to distinguish especially because coloration can vary within a species. Mean mercury concentrations in all crayfish samples ranged from 0.04 ppm to 0.66 ppm, and within the same species, ranged from 0.05 ppm to 0.66 ppm. OEHHA used the overall mean mercury concentration for all crayfish samples combined (0.20 ppm) to develop consumption guidelines.

The majority of black bass samples from the Sacramento River and Northern Delta were largemouth bass. Mean mercury concentrations were similarly high in largemouth, smallmouth, and spotted bass. In keeping with all other advisories in which OEHHA has combined black bass species, the mean mercury concentration for the species group (0.65 ppm) was used to develop consumption guidelines.

Several species, including steelhead trout, were not collected in sufficient numbers to evaluate, but could be compared to a related species. Steelhead and rainbow trout are essentially behavioral variations of the same species, and the average mercury concentration of steelhead trout, although only represented by four fish, was similar to rainbow trout (0.07 ppm and 0.04 ppm, respectively) and corresponded to the same consumption category. Both species were included together in the guidelines.

Eleven Chinook salmon were collected from the Sacramento River outside the Delta. Although the sample size was relatively small (even though it met the criterion), the range in mercury concentrations was narrow (0.04 ppm to 0.09 ppm). Additional samples of adult river-run salmon collected as they returned to salmon hatcheries (FMP data not shown) had comparably low mercury levels. Furthermore, salmon and trout are related (salmonid family) and individuals from salmonid species are typically similarly low in mercury when collected from free-flowing water bodies (as opposed to landlocked lakes and reservoirs). Therefore, the data were considered adequate to characterize the species. Salmon is one of the best sources of “omega-3” fatty acids, and therefore, providing consumption guidelines for river-run salmon is important to provide health-promoting options for consumers.

Goldfish were represented by only four fish but had a mean mercury concentration that was consistent with its relative, carp (0.26 ppm and 0.24 ppm, respectively). Hitch and hardhead also belong to the same family as carp and goldfish, and had comparable mean mercury concentrations (0.26 ppm and 0.26 ppm, respectively), though only seven hitch were included in this dataset. The individual species means and the combined species mean correspond to the same consumption category. Therefore, all four species were included in the advisory and assigned the same consumption advice.

The sample of tule perch consisted of only six individuals. This species belongs to the surfperch family, consisting mainly of marine species. Tule perch could not be compared to a related species in this evaluation and were not included in the guidelines. The two sturgeon[1] that were collected were insufficient for evaluation. The current advisory for San Francisco Bay applies to sturgeon from the Delta and is included here with the safe eating guidelines developed for the Sacramento River and Northern Delta.

For Sacramento pikeminnow, the MRC analysis showed that length explained over 50 percent of the mercury variance. Given the strong relationship between fish length and mercury concentration observed in the data for this species, issuing size-specific advice was considered for pikeminnow. The scatterplot in Appendix IX depicts the relationship between length and mercury concentrations in all samples of Sacramento pikeminnow from the Sacramento River and Northern Delta. The graph shows that, using the 95 percent confidence interval around the mean mercury concentration, pikeminnow of all sizes could exceed the threshold for no consumption. Therefore, OEHHA decided not to assign size-specific advice, and the overall species mean mercury concentration was used to develop guidelines for pikeminnow. The mean mercury concentration for pikeminnow was very close to the threshold between consumption and no consumption. Because there is no evidence to date that pikeminnow contain high levels of “omega-3”fatty acids, the decision was made to provide the more conservative guidelines. This

[1] Ten sturgeon were collected as part of the FMP; however, the laboratory did not analyze the sturgeon samples with the other FMP samples, nor did they subsequently provide analytical results to OEHHA.

decision is an example of using best professional judgment to balance the risks and benefits of fish consumption (Klasing and Brodberg, 2008).

Fifty-one striped bass were collected from various locations in the Northern Delta and Sacramento River (outside the Delta), and in Fremont Weir (also outside the Delta); the mean mercury concentration was 0.38 ppm. Striped bass were not included in the evaluation for the following reason. The FMP initiated a special study of striped bass that is underway at the time of writing. The study will analyze a total of about 100 striped bass from the Delta to provide data suitable for considering regional advice for this species and for updating the interim guidelines for striped bass that are currently included in the San Francisco Bay/Delta fish consumption advisory. In the time period until the special study is completed and evaluated, the San Francisco Bay fish consumption advisory for striped bass in the Delta remains in effect.

EVALUATION OF OTHER CONTAMINANTS IN FISH AND SHELLFISH FROM THE SACRAMENTO RIVER AND NORTHERN DELTA

Analysis of chlorinated hydrocarbon contaminants (including pesticides and PCBs) was planned as part of the sampling design for the FMP advisory sampling sites because developing comprehensive safe eating guidelines requires consideration of all potential chemicals of concern. The FMP, however, was funded by CBDA for the express purpose of assessing mercury contamination, and thus, outside sources of funding were sought for analysis of these other chemical contaminants. Fish tissues collected under the FMP were archived, and some of them were subsequently analyzed with support from the CVRWQCB and SRWP. As indicated above, OEHHA reviewed the preliminary data. In addition, data from limited analyses for select chlorinated hydrocarbon contaminants from historical datasets were also examined to determine whether any locations showed excessively high concentrations of these contaminants such that safe eating guidelines based on mercury would not be sufficiently health protective. The evaluation focused on the most common chlorinated hydrocarbon contaminants found in California sport fish: total PCBs; and the pesticides dieldrin, toxaphene, total chlordanes, and total DDTs. As was done with mercury data, OEHHA compared chlorinated hydrocarbon contaminant levels in fish and shellfish to OEHHA advisory tissue levels (Table 6), which are designed so that individuals consuming no more than a preset number of meals should not exceed predetermined thresholds for exposure to chemical contaminants.

Historical data on chlorinated hydrocarbon contaminants from the prior ten years (1997 to 2007) for the Sacramento River and Northern Delta region included 57 samples analyzed under SRWP from ten sampling locations and including nine species (Table 7). The concentrations of PCBs (analyzed as congeners) were slightly above the advisory tissue level (21 parts per billion, or ppb; Table 6) at which consumption recommendations would be limited to two meals a week in the following samples: one composite sample of pikeminnow from the Sacramento River at Alamar[1] (22 ppb); white catfish from the Sacramento River at Alamar, based on the mean of two samples (24 ppb); and an individual striped bass from the Sacramento River at Colusa (24 ppb). The species mean for two samples of Sacramento sucker from the Sacramento River at River Mile 44 was higher (42 ppb) but still within the same advice category as the above-mentioned samples. The mean concentrations of PCBs for these samples would not warrant advice more

[1] The Sacramento River at Alamar is the same location as the Sacramento River at Veteran's Bridge.

restrictive than that based on mercury. Pesticides in all SRWP samples were either low or not detected and were not of concern.

Four samples from the Sacramento River or Northern Delta were analyzed for chlorinated hydrocarbon contaminants in TSMP in the last ten years. One sample, which consisted of a composite of six white catfish collected in 1998 from the Sacramento River at Hood had the highest measured concentration of PCBs (200 ppb, measured as Aroclors; Table 8). At the same location, a composite of smallmouth bass had a low concentration of PCBs (10 ppb), and PCBs were not detected in a single largemouth bass. PCBs were not detected in the fourth sample, a composite of five largemouth bass from Prospect Slough. Pesticides were either low or not detected in these samples and were not of concern. The single catfish sample with elevated PCBs was not considered adequate to develop consumption advice due to the small sample size and lack of additional supporting data. However, it indicates that further sampling for chlorinated hydrocarbon contaminants is warranted.

In the FMP samples, 36 composite samples were analyzed from 13 sampling sites in the Sacramento River and Northern Delta region. Of these, two samples of channel catfish had elevated concentrations of PCBs (100 ppb from the Sacramento River at Colusa and 53 ppb from the Sacramento River at Veteran's Bridge); and one sample of carp, also from the Sacramento River at Veteran's Bridge, had a slightly elevated concentration of PCBs (26 ppb). PCB concentrations in these three samples were measured as the sum of 48 congeners (Table 9). At each of these sampling locations, an additional composite sample of Sacramento sucker had low total PCBs (measured as the sum of 48 congeners). The draft safe eating guidelines for both catfish and carp based on mercury would be protective for the PCBs content for women ages 18-45 and children ages 1-17. The channel catfish samples, however, suggest that more restrictive advice might be warranted for women over 45 and men because recommendations for this population based on mercury are less restrictive than for women ages 18-45 and children. The results for PCBs, however, are not only limited, but do not show consistent patterns either on a regional or more localized basis. High levels of PCBs were not found in species most likely to accumulate PCBs from multiple locations within an area, and no sampling sites had consistently high concentrations of PCBs in multiple species. The remaining 33 FMP samples collected from sampling locations on the Sacramento River or in the Northern Delta had non-detectable or low concentrations of PCBs. All FMP samples analyzed for chlorinated hydrocarbon contaminants had non-detectable or low concentrations of pesticides and were not of concern. Therefore, safe eating guidelines for the Sacramento River and Northern Delta were based on mercury concentrations only.

GUIDELINES FOR FISH CONSUMPTION

OEHHA generally issues site-specific consumption advice beginning at a consumption frequency of one eight-ounce meal per week (a total of six ounces of cooked fish per week), which is equivalent to two three-ounce servings or the minimum weekly fish consumption rate recommended by the American Heart Association (AHA, 2007). Fish that can be eaten at this frequency represent fish with relatively low levels of mercury or other contaminants. If fish can be consumed even more frequently than one "meal" or a total of six ounces of cooked fish per week, based on very low contaminant concentrations, advice for consumption of two or three meals per week may also be provided. In addition, because of the potential beneficial effects from regular fish consumption, thought to stem largely from unique "omega-3" fatty acids in fish, OEHHA encourages people of all ages, especially women 18-45 years and children 1-17 years, to eat fish that are low in mercury or other contaminants and high in “omega-3” fatty acids. OEHHA recommends that consumers avoid regular consumption of fish that cannot be safely eaten at a minimum of six ounces (after cooking) a week.

Mean mercury concentrations for species and species groups were compared to advisory tissue levels, as discussed above, to ascertain the appropriate recommendations for consumption, or safe eating guidelines presented below. Concentrations of PCBs were also compared to advisory tissue concentrations for PCBs, and the corresponding advice categories were reviewed to determine whether the mercury guidelines were adequately health protective for PCBs as well. As indicated above, safe eating guidelines derived from mercury concentrations were found to be health protective for PCBs based on the available data.

Recommendations for women 18-45 years, including pregnant and breastfeeding women, and children 1-17 years for eating fish and shellfish from the Sacramento River and Northern Delta

- Women 18-45 years and children 1-17 years can eat a total of three servings a week from the following species: Asiatic clams, rainbow trout, steelhead trout, Chinook salmon, and American shad. Serving size for women is six ounces of fish after cooking (equal to eight ounces before cooking). Serving size for children up to age 12 is about half as much as adults (three ounces of cooked fish).
- Alternatively, a maximum of one serving a week can be eaten of one of the following species: Sacramento sucker, sunfish (including bluegill and redear sunfish), crayfish, carp, goldfish, hardhead, hitch, crappie, or catfish (including channel or white catfish, or bullhead).
- It is recommended that Sacramento pikeminnow and black bass (including largemouth, smallmouth, and spotted bass) not be eaten.
- The 1994 advisory for San Francisco Bay and the Delta recommends that women ages 18-45 and children eat no striped bass over 27 inches. The San Francisco Bay/Delta advisory allows for consumption of one meal a month of smaller legal-sized striped bass, or sturgeon, but if striped bass or sturgeon is eaten by women ages 18-45 or children, it is recommended that no other fish be eaten that month. In this advisory, a meal was defined as six ounces of fish after cooking (eight ounces before cooking) for a 160-pound adult; children should eat smaller meals.

Recommendations for women over 45 years and men for eating fish and shellfish from the Sacramento River and Northern Delta

- Women over 45 and men can eat one serving a *day* from the following species: Asiatic clams, rainbow trout, steelhead trout, Chinook salmon, and American shad. Serving size is six ounces of fish after cooking (about eight ounces before cooking) for an adult weighing about 160 pounds. Serving size can be adjusted to add one ounce for every 20 pounds above, or subtract one ounce for every 20 pounds below, the average weight of 160 pounds.
- As an alternative, women over 45 and men can eat up to three servings a week from the following species: Sacramento sucker, sunfish (including bluegill and redear sunfish), and crayfish.

- Alternatively, women over 45 and men can eat up to two servings a week from the following species: carp, goldfish, hardhead, hitch, crappie, or catfish (including channel and white catfish, or bullhead).
- Alternatively, women over 45 and men can eat a maximum of one serving a week of pikeminnow or black bass (including largemouth, smallmouth, and spotted bass).
- The 1994 advisory for San Francisco Bay and the Delta recommends that women over 45 and men eat no more than two meals a month of sturgeon or striped bass from the bay or Delta, and eat no striped bass over 35 inches. If striped bass or sturgeon is eaten by women over 45 years or men, however, it is recommended that no other fish be eaten that month. In this advisory, a meal was defined as six ounces of fish after cooking (eight ounces before cooking) for a 160-pound adult.

Other Recommendations

Regular consumption of fish is recommended as part of a healthy diet due to evidence for health benefits associated with consistent fish consumption (AHA, 2007, IOM, 2007). The “one meal a month” advice used in previous advisories has been combined with the “no consumption” category in recent advisory tables and labeled “do not eat” to reflect that eating fish from this category is not health protective because the higher levels of mercury prevent regular safe consumption of fish. The San Francisco Bay/Delta advisory, however, recommended consumption for women 18-45 years and children of up to one meal a month, and for women over 45 and men, up to two meals a month. These guidelines currently apply to striped bass and sturgeon from the Delta and Sacramento River, as well as other San Francisco Bay fish. This advice will be maintained until the results of the striped bass study, as mentioned above, are evaluated, although it is not consistent with recent OEHHA guidelines to avoid fish that can only be eaten once a month. It should be noted that even though striped bass do contain fairly high “omega-3” fatty acid levels, consumption of one or two meals a *month* will not provide an adequate intake of “omega-3” fatty acids. Therefore, OEHHA encourages consumers to select fish for consumption that can be safely eaten more than once or twice a month and that contain higher levels of “omega-3” fatty acids. Typically, these species include river-run salmon and trout, and for women over 45 and men only, black bass including largemouth, smallmouth, and spotted bass. To obtain adequate levels of “omega-3” fatty acids, especially at water bodies with limited or no species that can be eaten one or more times a week), consumers are advised to maintain regular consumption of fish by eating sport fish from other water bodies with less restrictive advice, or low-mercury commercial fish that are high in “omega-3” fatty acids from stores or restaurants (including salmon, trout, herring, and sardines), in order to obtain the health benefits from fish consumption. Newer safe eating guidelines from OEHHA will indicate fish species with high “omega-3” levels.

It is very important to note that if an individual consumes multiple species or catches fish from more than one location with an advisory, the recommended guidelines for different species and locations should not be combined (*i.e.*, added). If a person eats six ounces of cooked fish with a recommendation of one serving a week, no other fish should be eaten that week. An individual can eat one species of fish one week, and the same or a different species from the one-serving category the next week. When the recommended consumption is two or three servings a week, fish species in that category can be interchanged, but not added to consumption of a species from the one-serving-a-week category. Salmon and trout are among the best choices for all consumers because they are very low in mercury and high in "omega-3" fatty acids. Regular consumption of salmon and trout by pregnant women can confer neurological advantages to the developing fetus (Oken *et al.*, 2005; Cohen, *et al.*, 2005).

OEHHA also recommends that women ages 18-45 and children ages 1-17 follow the Joint Federal Advisory for Mercury in Fish for commercial fish (U.S. EPA, 2004, see http://www.epa.gov/waterscience/fishadvice/advice.html). This advisory recommends that these individuals do not eat shark, swordfish, king mackerel, or tilefish[1] because of the high levels of mercury in these species. The federal advisory also states that these individuals can safely eat up to two meals (12 ounces cooked) of a variety of other fish purchased at stores or restaurants such as shrimp, canned light tuna, wild salmon, pollock, or (farm-raised) catfish. Albacore ("white") tuna is known to contain more mercury than canned light tuna; it is therefore recommended that no more than six ounces of albacore tuna (*e.g.*, one six-ounce can) be consumed per week.

For fish consumers who only eat sport fish occasionally, for example, on an annual vacation, consumption of a relatively high mercury species such as striped bass or largemouth bass from the Sacramento River or Northern Delta would not be a cause for concern provided their other fish intake did not include regular consumption of high-mercury commercial fish.

For general advice on how to limit your exposure to chemical contaminants in sport fish (*e.g.*, eating smaller fish of legal size), as well as a fact sheet on methylmercury in sport fish, see the California Sport Fish Consumption Advisories (http://www.oehha.ca.gov/fish.html) and Appendices I and III. Unlike the case for many fat-soluble chlorinated hydrocarbon contaminants (*e.g.*, DDTs and PCBs), however, various cooking and cleaning techniques will not reduce the methylmercury content of fish. Additionally, there are no known ways to prepare fish (such as soaking in milk) that will reduce the methylmercury content of the fish. Meal sizes should be adjusted to body weight. Consumers weighing less than 160 pounds should eat smaller portions than the standard eight-ounce portion (equal to six ounces after cooking), and children should also eat smaller portions, about half as much as adults for children up to the age of 12. The complete draft recommendations (safe eating guidelines) for consumption of fish and shellfish from the Sacramento River and Northern Delta for women 18-45 years and children 1-17 years, and for women over 45 years and men are presented in the guides below.

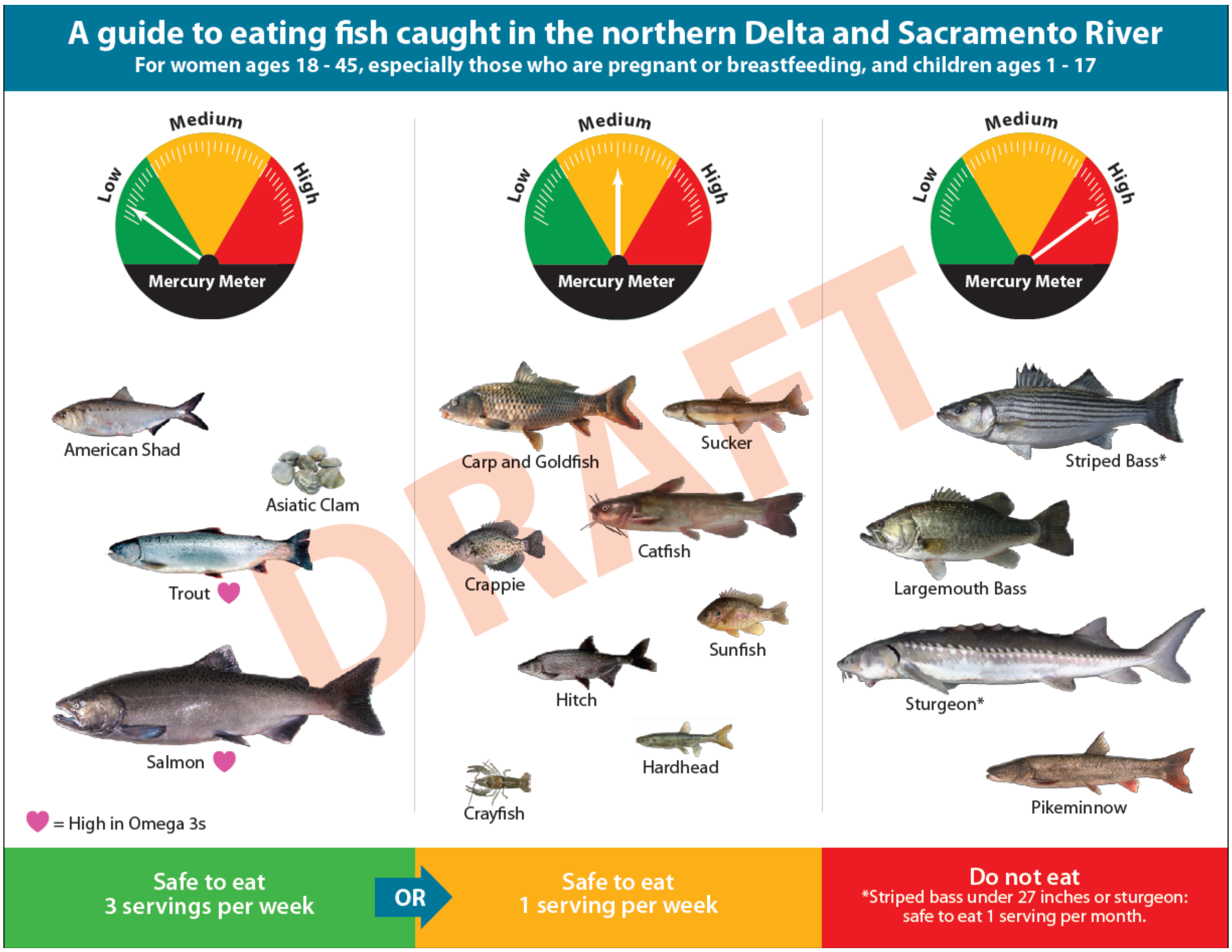
[1] King mackerel and tilefish are common on the east coast but rarely found in California or other western states, whereas shark and swordfish are more commonly available on the west coast.

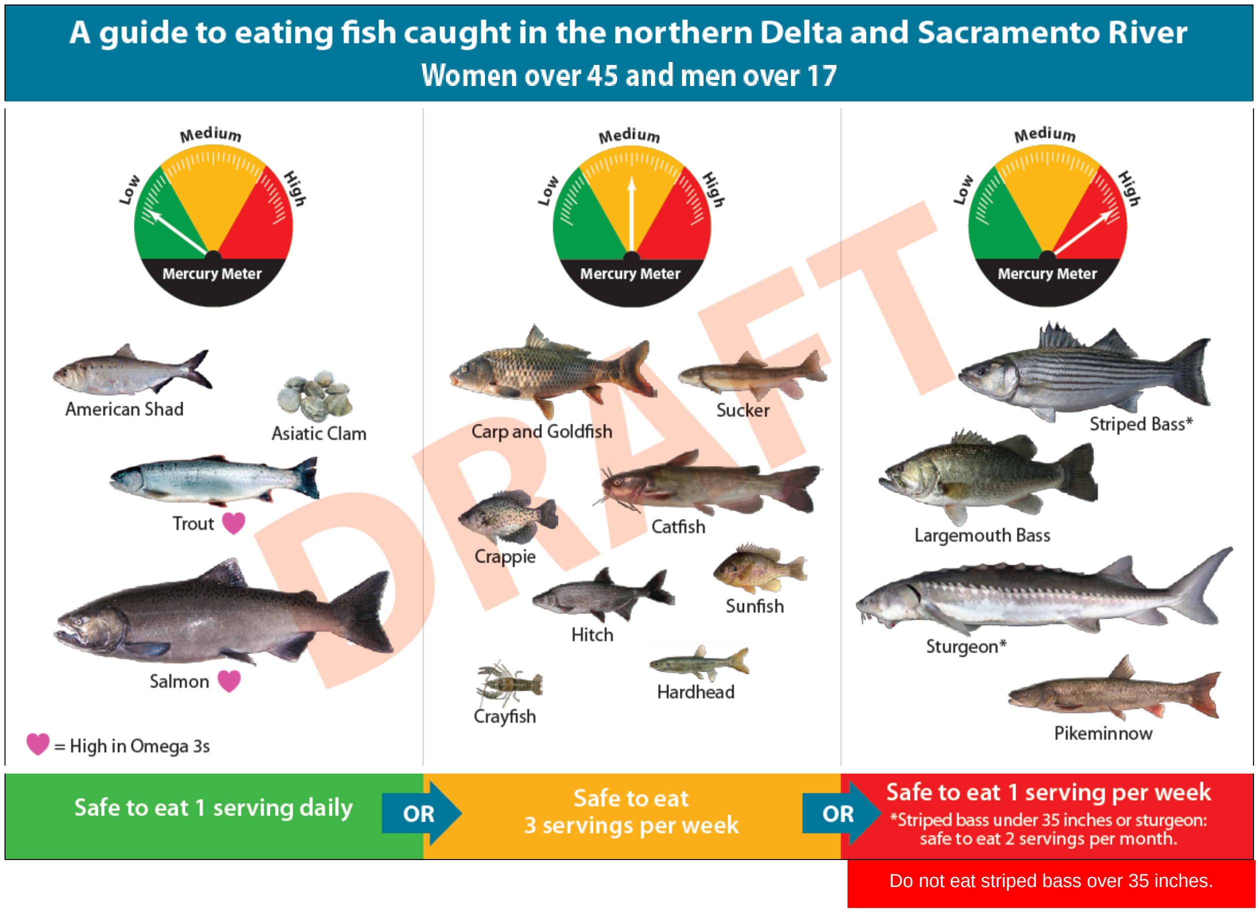
DRAFT SAFE EATING GUIDELINES

Based on Mercury in Fish from the

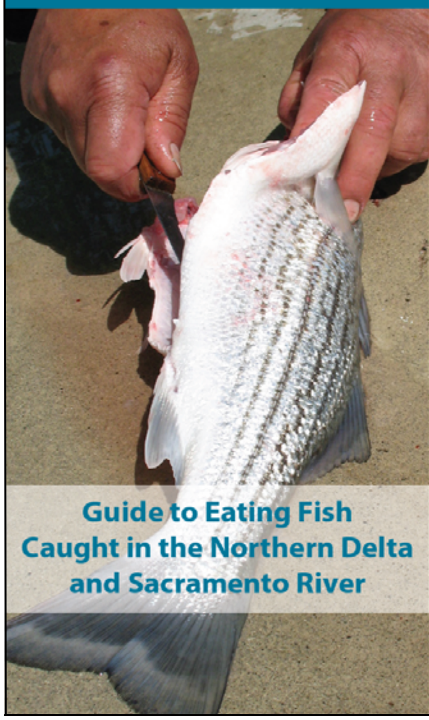
Sacramento River and Northern Delta

Including the Sacramento River from below Shasta Lake to Pittsburg
and other water bodies in the Delta north of Highway 12




A guide to eating fish caught in the northern Delta and Sacramento River
Women over 45 and men over 17
Medium
Low
High
Mercury Meter
American Shad
Asiatic Clam
Trout
Salmon
= High in Omega 3s
Medium
Low
High
Mercury Meter
Carp and Goldfish
Sucker
Catfish
Crappie
Sunfish
Hitch
Hardhead
Crayfish
Medium
Low
High
Mercury Meter
Striped Bass*
Largemouth Bass
Sturgeon*
Pikeminnow
DRAFT
Safe to eat 1 serving daily
OR
Safe to eat
3 servings per week
OR
Safe to eat 1 serving per week
*Striped bass under 35 inches or sturgeon:
safe to eat 2 servings per month.
Do not eat striped bass over 35 inches.

Eat fish.
Be safe.
Choose wisely.



Why eat fish?

Eating fish is good for your health. Fish have Omega 3s that can reduce your risk for heart disease and improve how the brain develops in unborn babies and children.

What is the concern?

Some fish have high levels of mercury that can negatively affect how the brain develops in unborn babies and children.

What should I do?

- Use this guide to choose fish lower in mercury and high in Omega 3s.
- Eat smaller fish of legal size. Fish build up mercury in their bodies as they grow.

What is a serving?

The recommended serving of fish is about the size and thickness of your hand. Use your hand to measure a serving of fish. Give children smaller servings.

More fish eating advice for women ages 18 – 45 and children ages 1 – 17

- You can eat 2 servings per week of fish from stores or restaurants. But, do not eat fish caught by you, friends or family in the same week.
- Only one of your two servings of fish per week should be canned albacore (white) tuna.
- When shopping for fish, good choices are salmon, pollock, catfish, tilapia, and shrimp.
- Do not eat shark, swordfish, tilefish, or king mackerel. These fish are very high in mercury.

For more advice about what you can do to protect your family from mercury in fish, contact:

OEHHA

http://www.oehha.ca.gov/fish.html.

(916) 327-7319 or (510) 622-3170

California Environmental Protection Agency
Office of Environmental Health Hazard Assessment
1515 Clay Street, 16th floor
Oakland, California 94612

RECOMMENDATIONS FOR FURTHER SAMPLING

Several local fish species were collected in very small numbers or not at all, for example, tule perch and Sacramento perch, respectively. Data on the abundance of these species and their popularity for consumption are needed to determine whether further sampling and analysis of these species would be recommended. The results of sampling and analysis of fish and shellfish for chlorinated hydrocarbon contaminants (including pesticides and PCBs) in recent years have generally indicated low levels of these contaminants in the Sacramento River and Northern Delta; however, a few samples have shown somewhat elevated concentrations of PCBs at a few locations. Additional evaluation of PCBs would be useful to confirm that PCBs are not accumulating to levels of concern in the Sacramento River or Northern Delta. OEHHA also recommends that salmon and trout be evaluated for chlorinated hydrocarbon chemicals.

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